Marty Mlynczak [1]

Luca Palchetti [2], Helen Brindley [3], and Hilke Oetjen [4]

and

The FORUM Science Team and Mission Advisory Group

[1] NASA Langley, Hampton, US; [2] INO-CNR Florence, IT ;
[3] Imperial College, London; [4] ESTEC, Noordwijk, NL

FORUM Mission Overview

- FORUM is a new space flight mission announced 9/2019 by the European Space Agency as its 9th Explorer Mission
- FORUM directly measures the previously unobserved far-infrared wavelengths longer than 15.5 μm (650 cm^{-1})
- FORUM mission consists of a Fourier Transform Spectrometer (FTS) for measuring the infrared spectrum and an imager for scene identification
- FORUM will fly in approximate formation with one of the METOP satellites and will have close synergy with IASI
- Launch is NET 2025

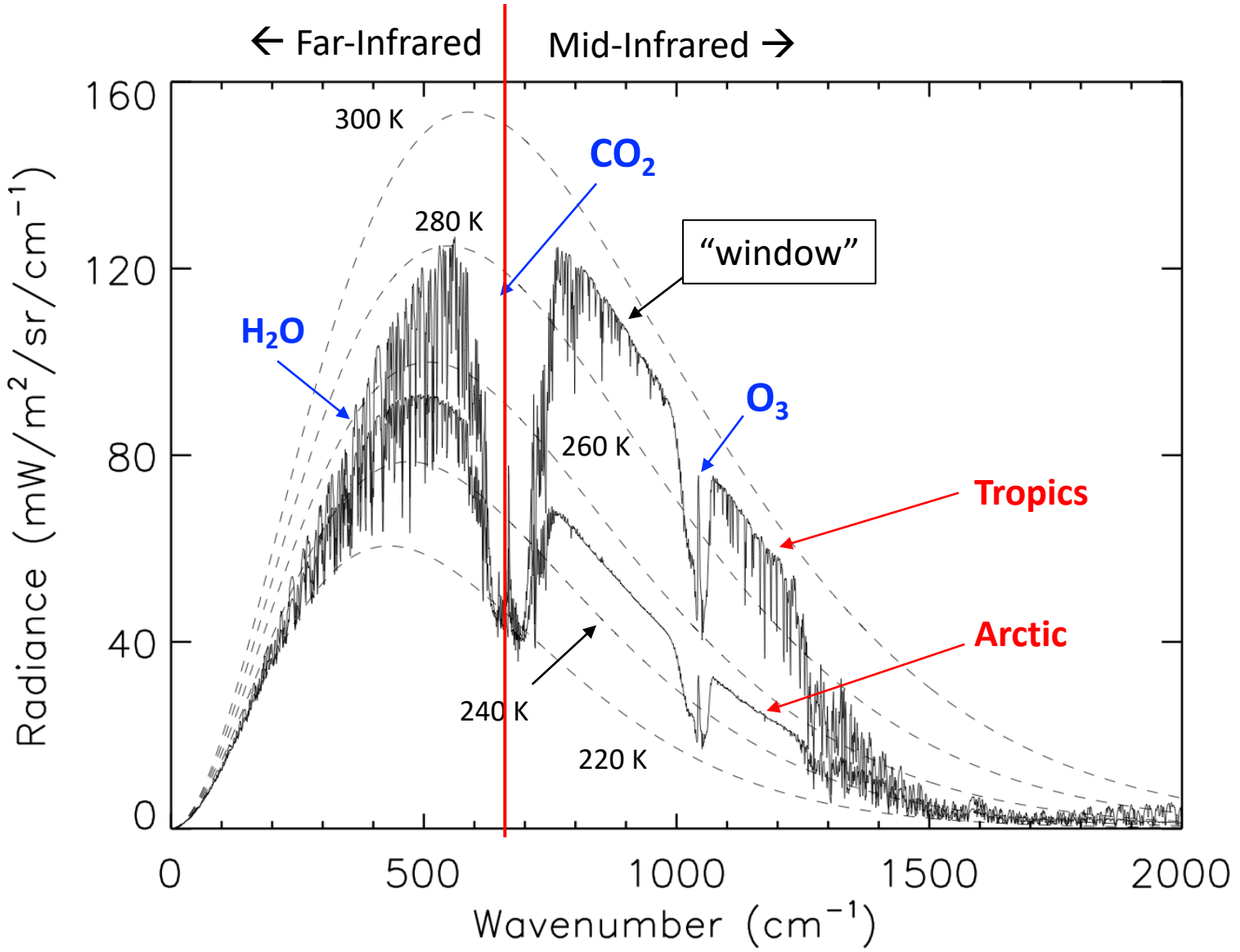
FORUM Background

- FORUM is the culmination of a 20-year international quest to achieve direct measurement of the far-IR from space
- Multiple teams developed ground, aircraft, and balloon-borne instruments to demonstrate science need and technology for measuring the far-IR
- These include:
  - Tropospheric Airborne FTS (TAFTS) – Imperial College, UK
  - Radiation Explorer in the Far-InfraRed (REFIR) – Italy
  - Far-Infrared Spectroscopy of the Troposphere (FIRST) – NASA
  - Atmospheric Emitted Radiation Interferometer (AERI Extended) – U. Wisconsin
- A number of aircraft flights, balloon flights, and ground campaigns since late 1990's
- In addition, spectroscopy of the far-IR, the water vapor continuum, has been and continues as a forefront of scientific inquiry

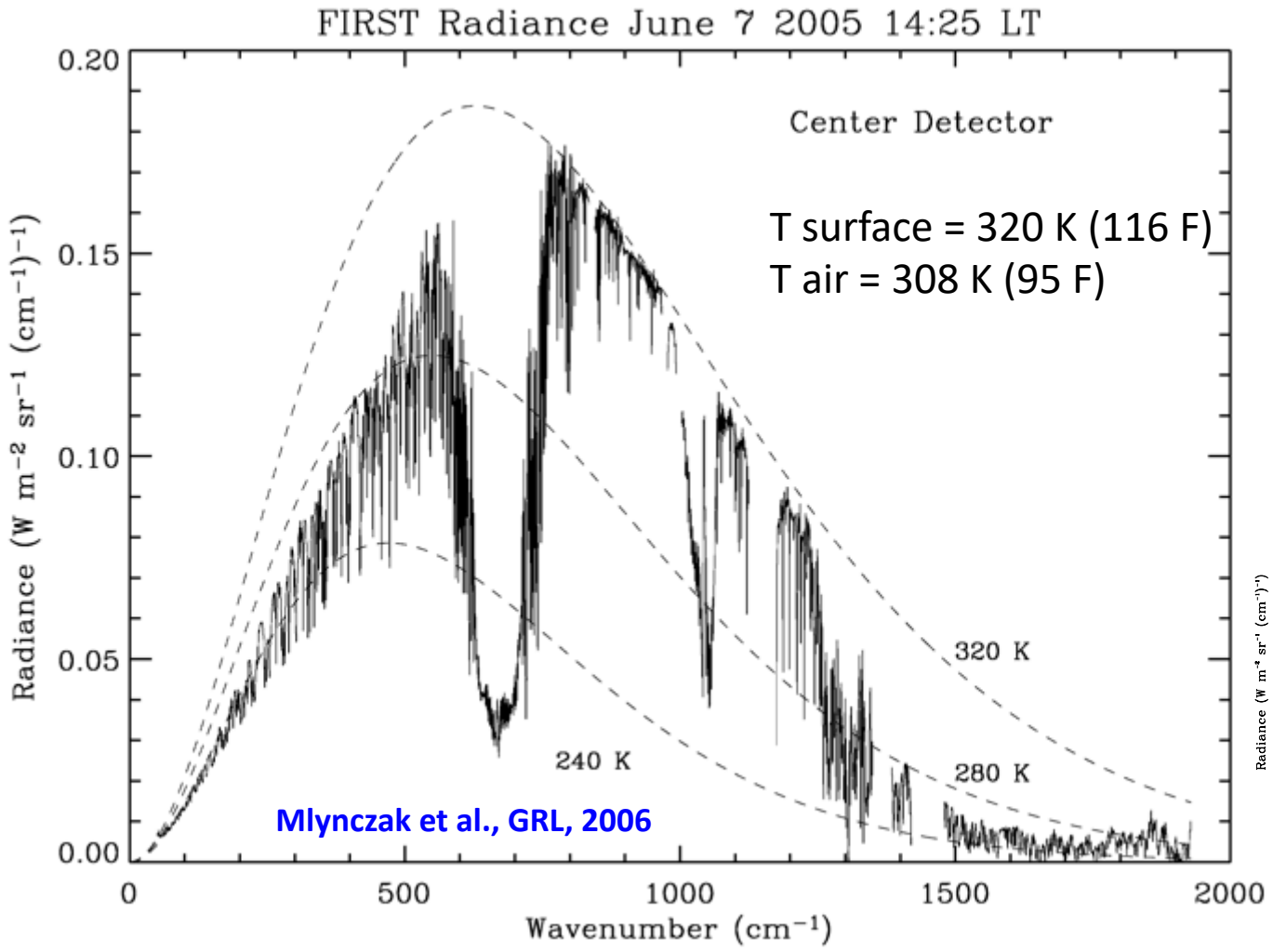
FORUM Proposing Team

Palchetti Luca	INO–CNR, Florence, IT
Ade Peter	Univ. of Cardiff, UK
Allan Richard	University of Reading, UK
Baran Anthony	Met Office, UK
Brindley Helen	Imperial College London, UK
Camy-Peyret Claude	IPSL, UPMC, Paris, FR
Cortesi Ugo	IFAC–CNR, Florence, IT
Dinelli Bianca Maria	ISAC-CNR, Bologna, IT
Feldman Daniel	L.Berkeley National Lab., US
Huang Xianglei	CSSE–Univ. of Michigan, US
Laurent Labonnote	LAO – Université de Lille, FR
Maestri Tiziano	DIFA – University of Bologna, IT
Martin-Torres Javier	Luleå Univ. of Technology, SE
Mlynczak Martin	NASA Langley Research Center, US
Ortolani Alberto	IBIMET–CNR, Florence, IT
Serio Carmine	SI – University of Basilicata, IT
Tett Simon	University of Edinburgh, UK
Wild Martin	IACS, ETH Zürich, CH

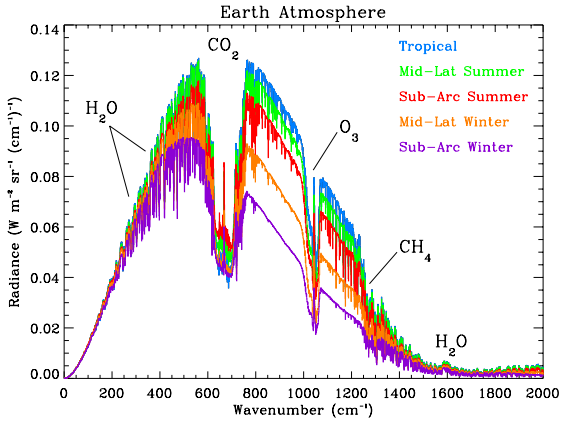
Tropical & Arctic Top-of-Atmosphere Emission Spectra



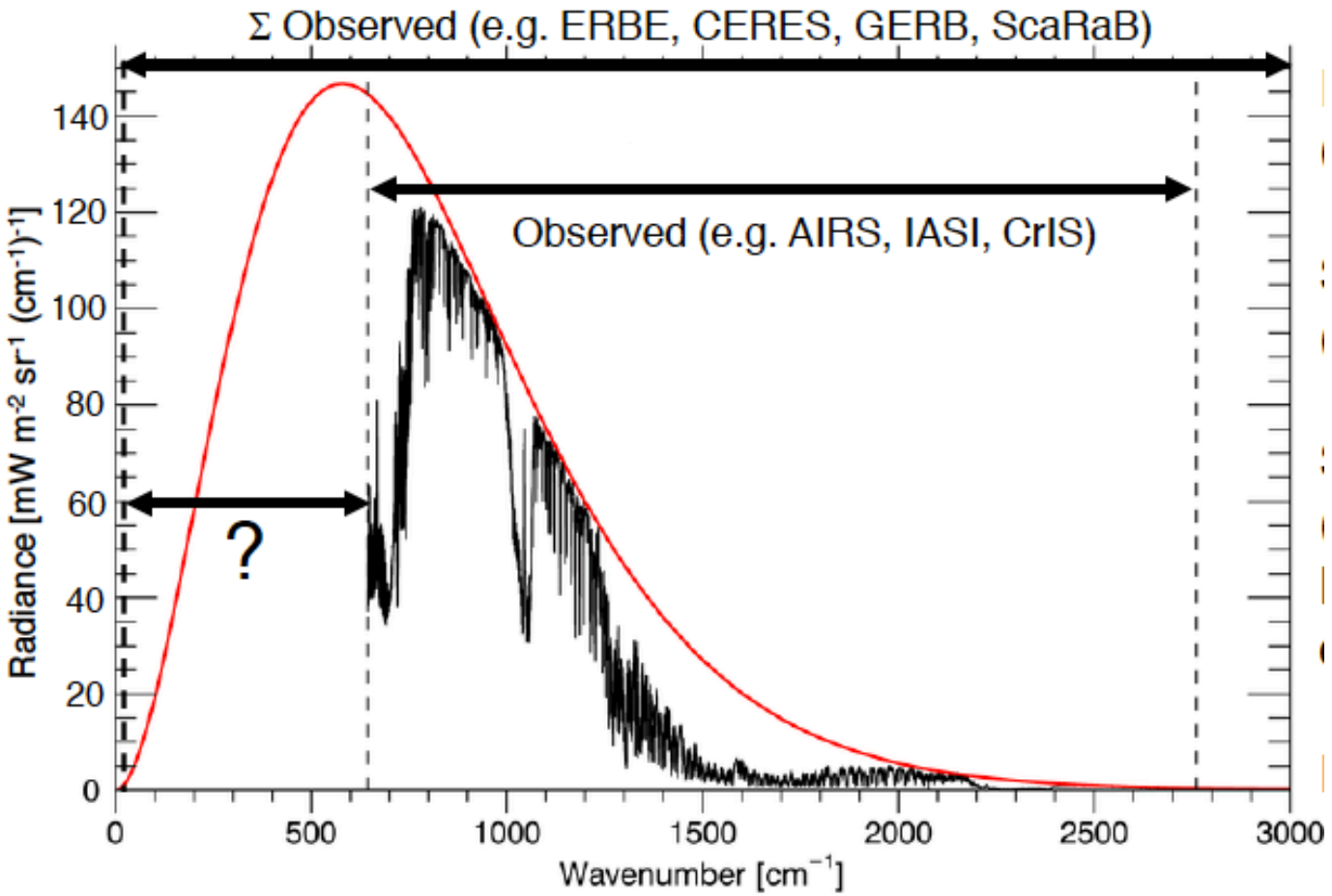
Measured Top-of-Atmosphere IR Spectrum



Ft. Sumner, NM



The missing link: Far-Infrared Spectra



Broadband integrated radiation (ERBE, CERES ,GERB, ScaRAB) since 1975

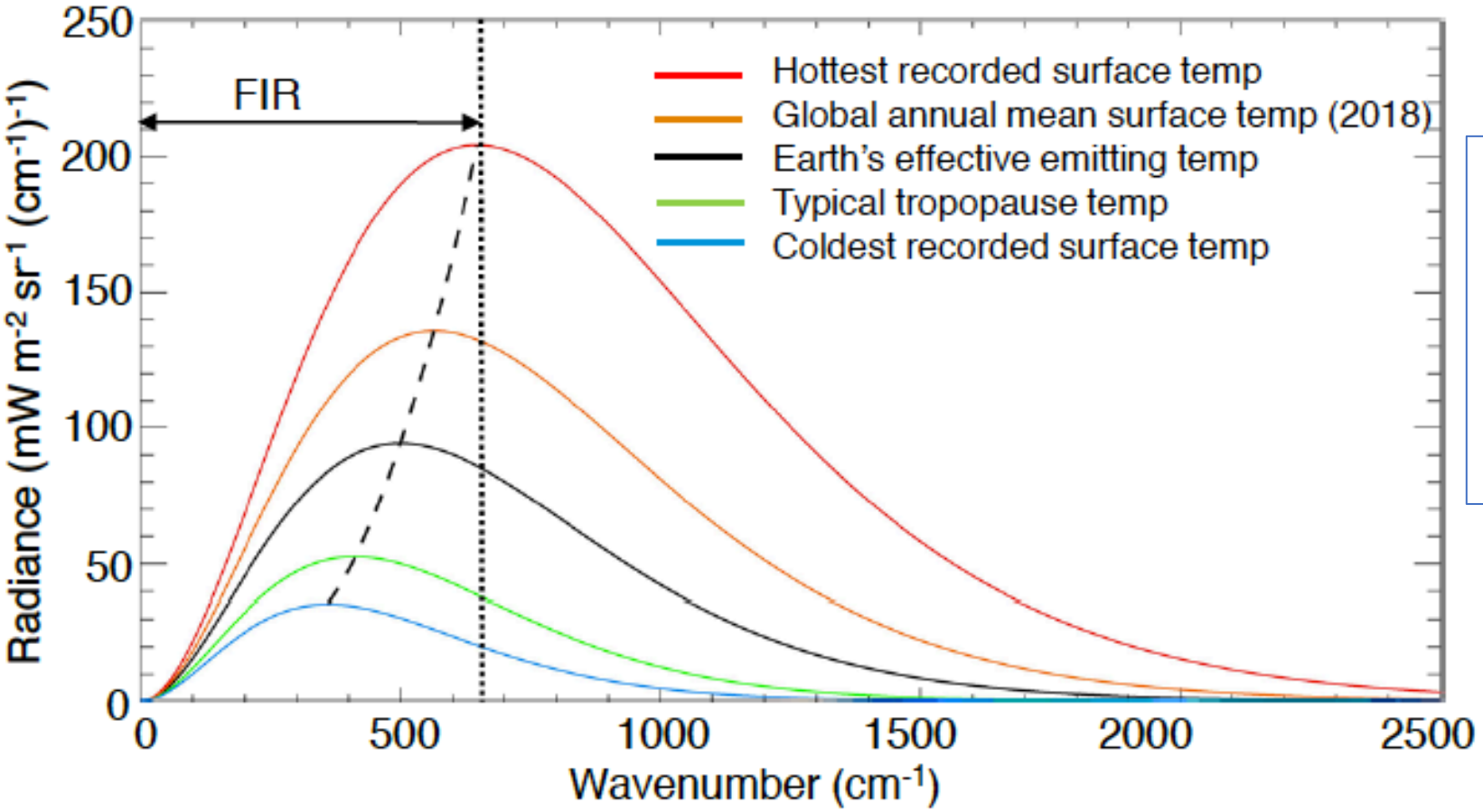
Mid-IR spectra (5-15 um; AIRS, IASI, CrIS) continuous since 2002

No science quality far-IR spectra from space (Nimbus-III and Nimbus-IV < 10 months)

No observations < 400 cm^{-1}

FORUM fills the critical gap!!

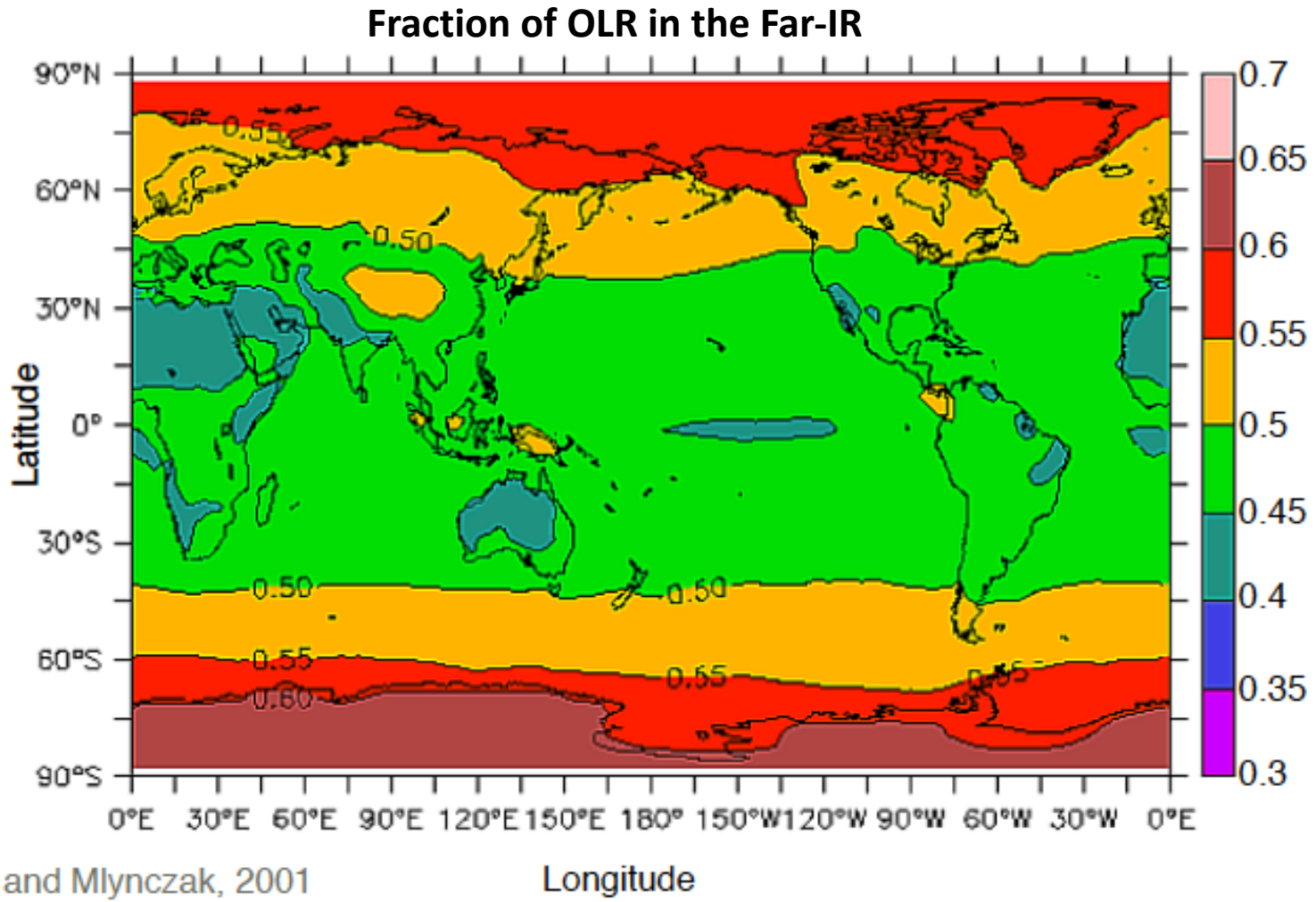
Why is the Far-IR so special?



Over the observed range of Earth's surface temperature and atmosphere, **the peak energetic emission** is in the far-infrared!

Why is the Far-Infrared so special?

Consistent with the TOA spectra, the Global OLR is dominated by the Far-IR

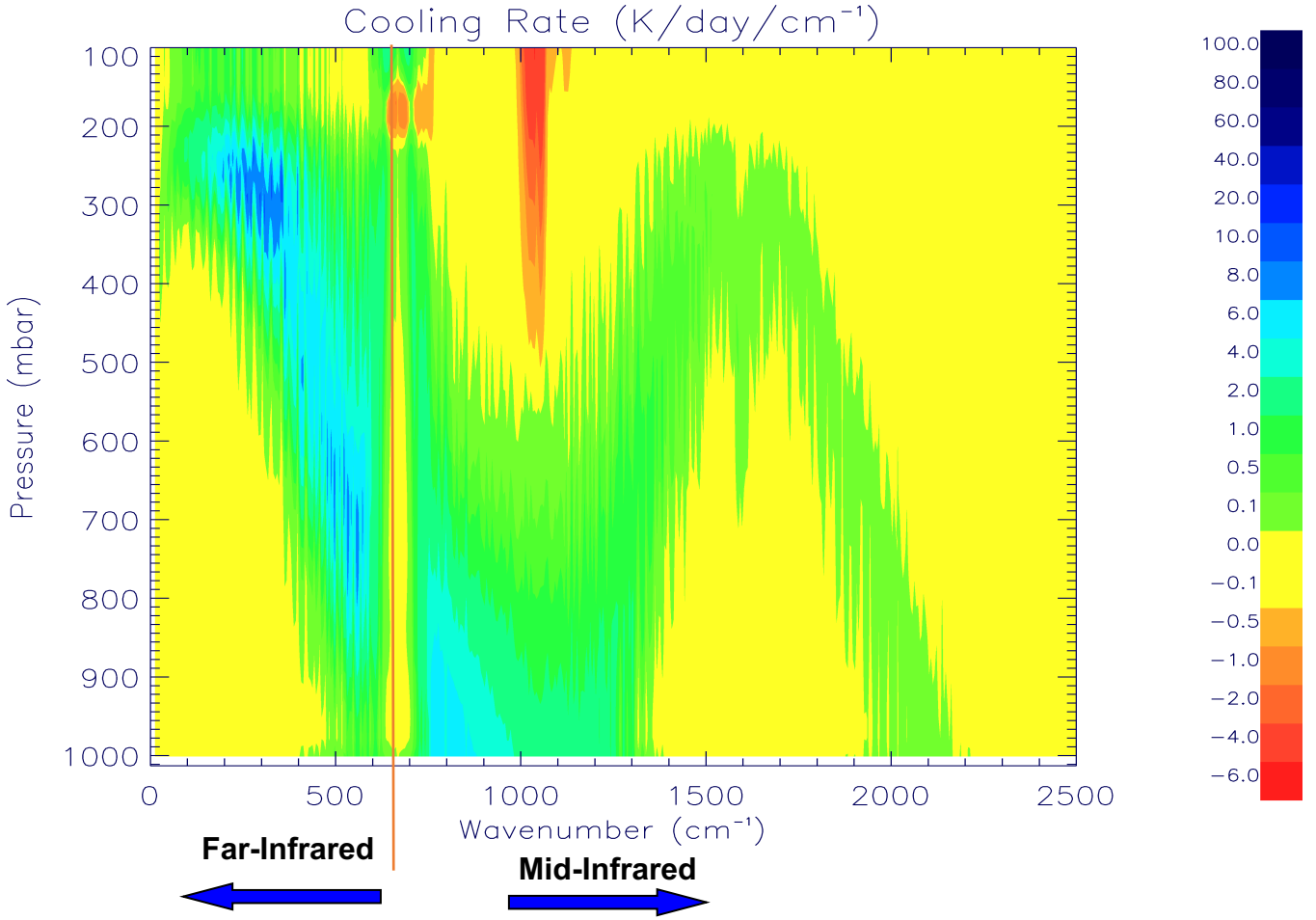


Collins and Mlynczak, 2001

Importance of the Far-IR: Infrared Radiative Cooling Rate

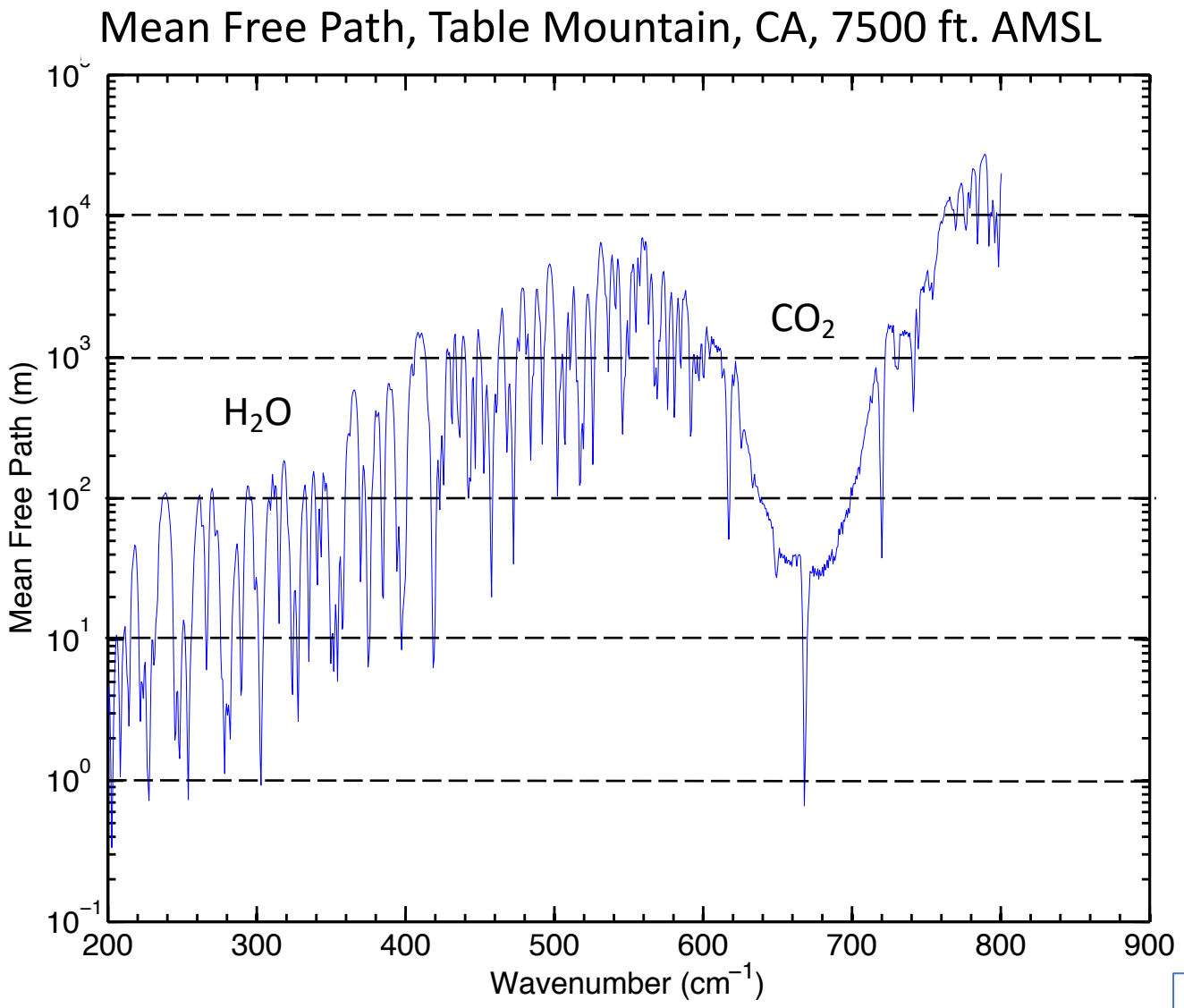
Impact throughout the atmosphere:

Dominant contribution to clear-sky atmospheric radiative cooling also located within the far-infrared: key driver of atmospheric dynamics



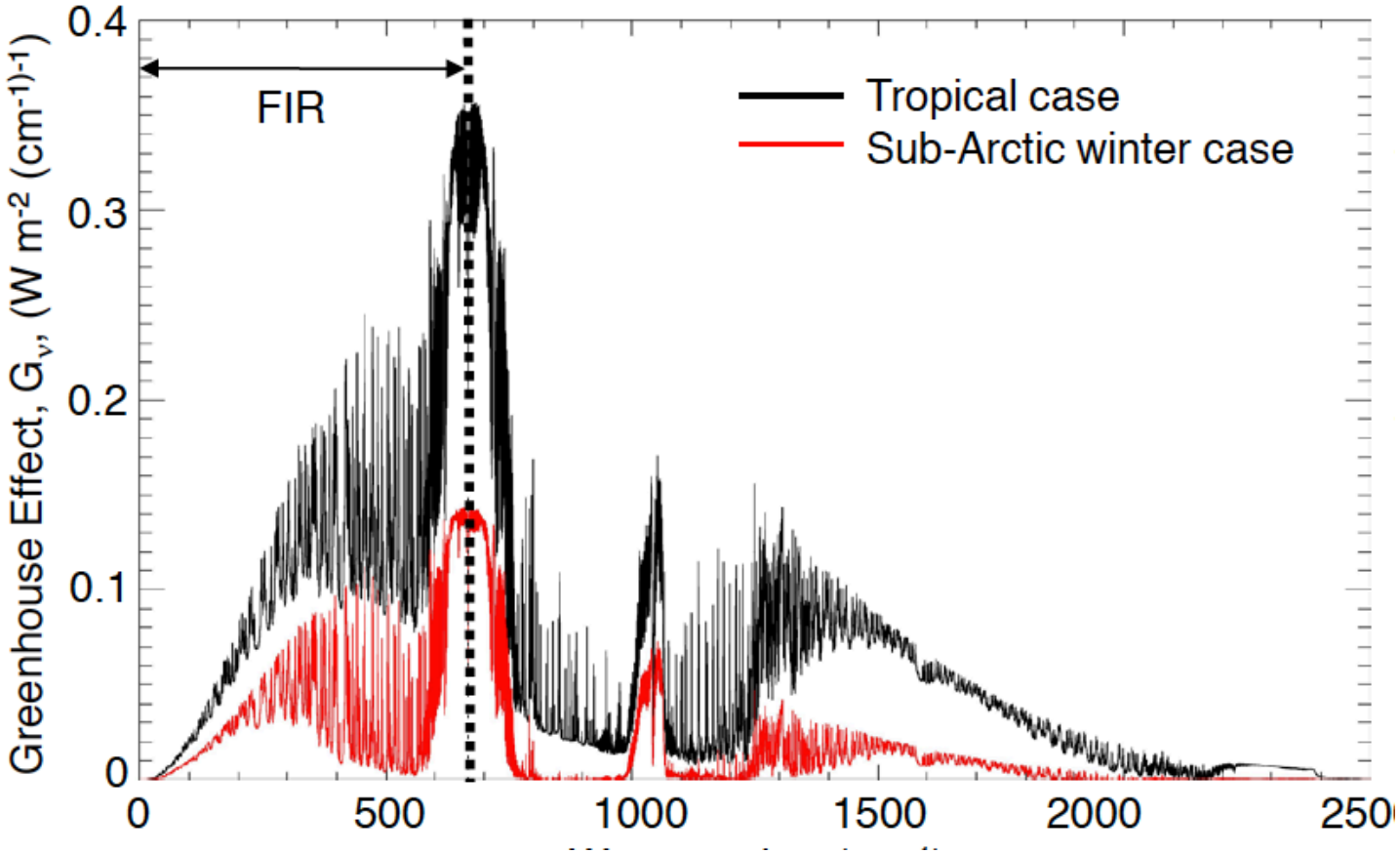
Far-IR and Atmospheric Opacity – Photon Mean Free Path

Precipitable Water
0.3 cm



Mlynczak et al., JQSRT, 2016

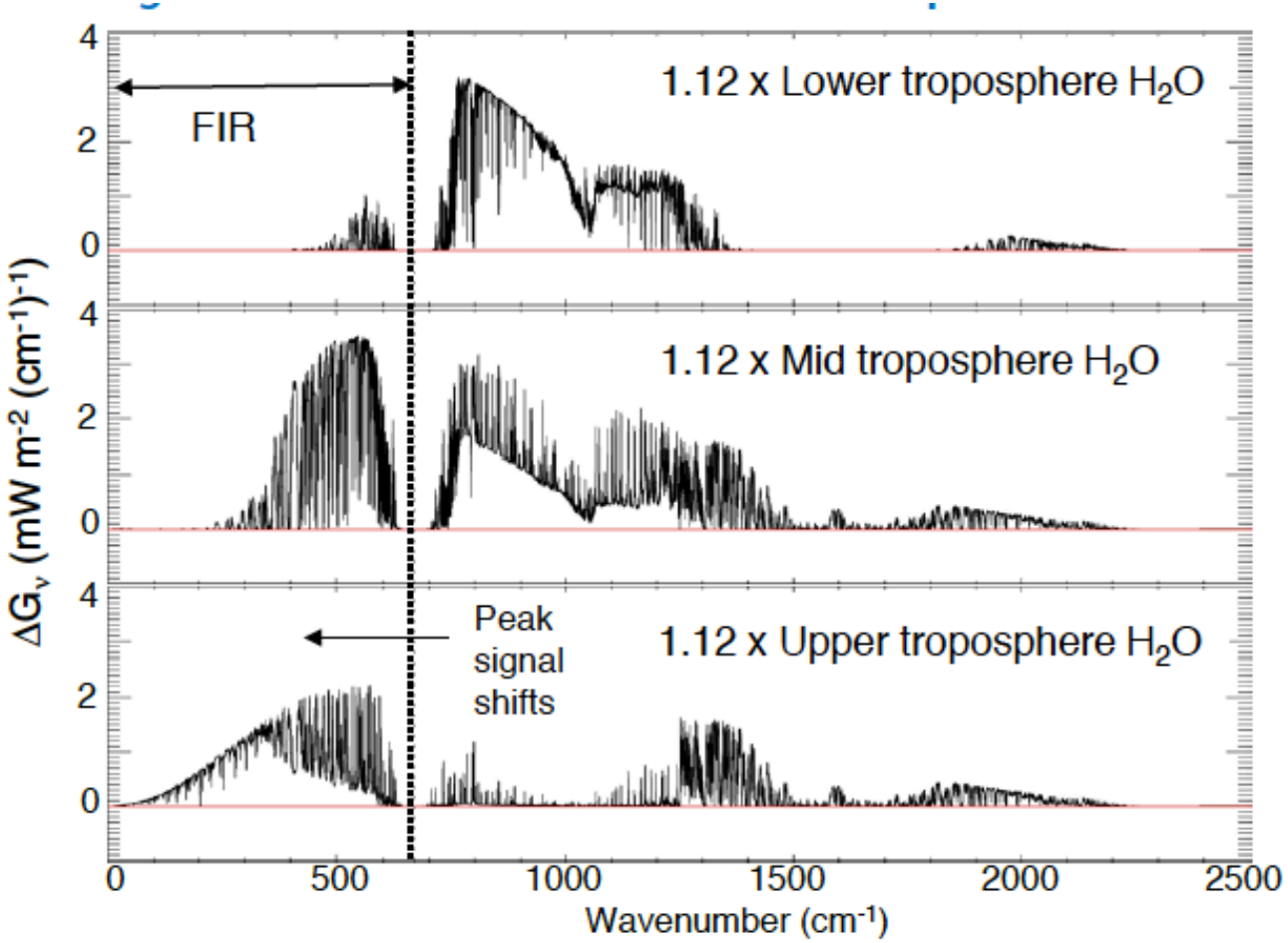
Why is the Far-Infrared so special? – Greenhouse Effect



Contribution to atmospheric trapping:

Absorption in the far-infrared contributes ~ 50 % to the total clear-sky Greenhouse Effect, G_ν

The Greenhouse Effect: Sensitivity to water vapor in Far-IR



Signatures of changes in atmospheric water vapour:

A small increase in water vapour can induce a change in trapping equivalent to doubling CO_2.

Significant fraction in far infrared, especially if the perturbation occurs in the colder upper-troposphere

FORUM: A true explorer

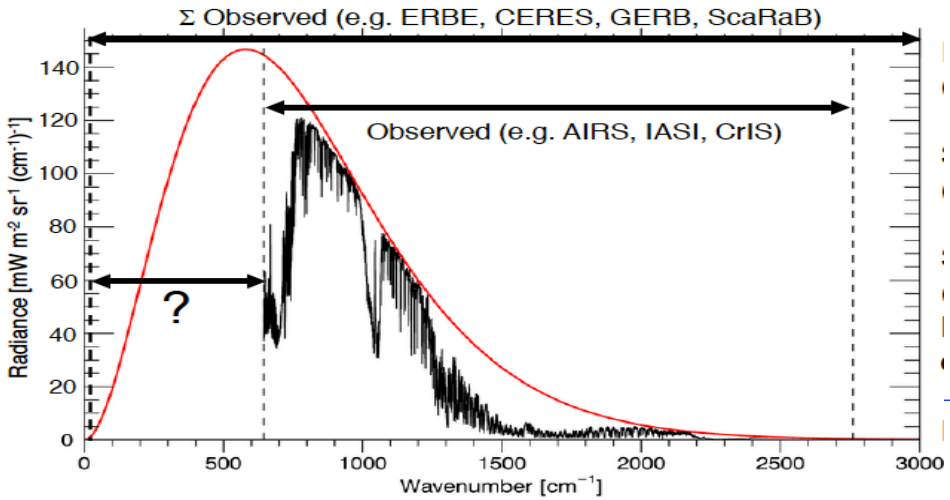
Research Objective

- to evaluate the role of the far-infrared in shaping the current climate and thus reduce uncertainty in predictions of future climate change

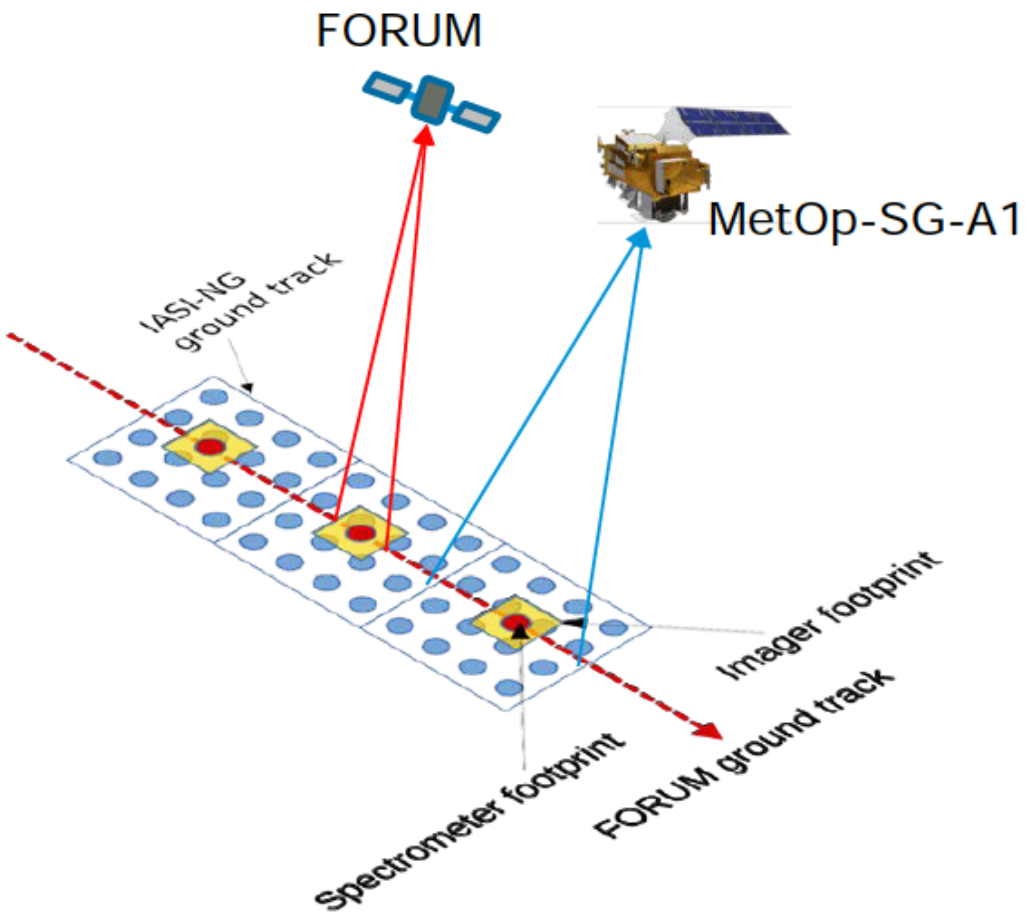
by

- building a highly accurate global dataset of far-infrared radiances for validation of the present-day state as captured by Earth system models
- using these measurements to understand and constrain the processes that control far-infrared radiative transfer and hence the Earth's Greenhouse Effect
- updating the parametrisations of these processes for implementation in radiative transfer codes, and ultimately in Earth system models
- characterising critical feedback mechanisms

Additional benefit for ice cloud, surface emissivity and water vapour retrievals



Mission Concept: Footprint and Spatial Sampling



Nadir-looking observations

Spectrometer footprint
- single circular **pixel Ø = 15 km**

Along-track sampling step
Goal = 70 km, Threshold = 100 km

Thermal imager footprint
- 60x60 pixels, 36x36 km²
- **resolution = 0.6 km**

Lifetime = at least 4 years to resolve seasonal & inter-annual variability

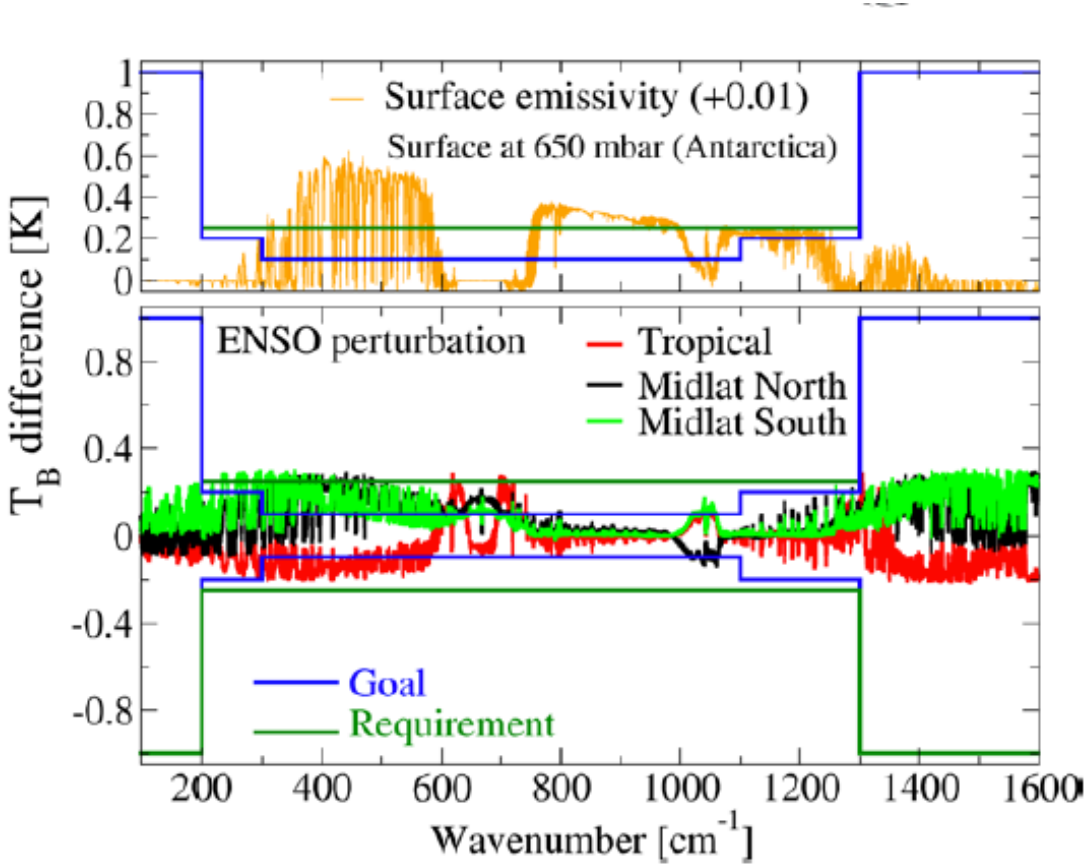
Flight in **loose formation with MetOp-SG-A1**
LEO, SSO at 9:30 LTDN – average altitude = 830 km to exploit synergy with IASI-NG

FORUM Absolute Radiometric Accuracy

Radiometric accuracy is the difference between the true value and the measurement in absence of random errors

High accuracy is required at 3σ

- to provide benchmark spectral observations against which climate models and future observations can be compared, which is the overarching goal of FORUM
- to derive FIR surface emissivity with accuracy better than 0.01
- to observe the effects of small perturbations in UTLS due to ENSO, QBO, etc. on zonal, monthly means

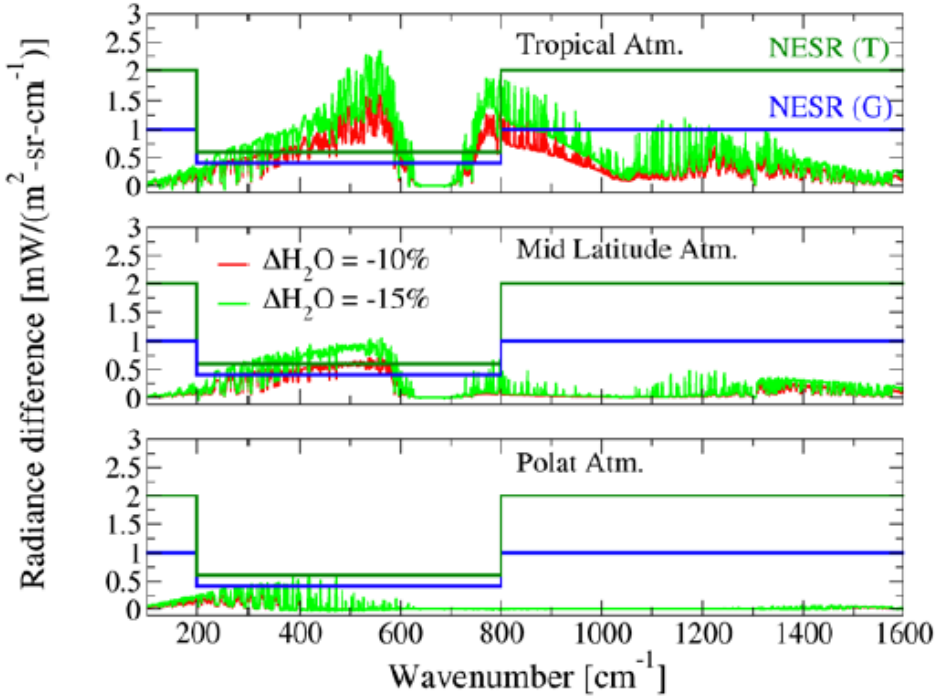


Goal = 0.1 K in 300-1100 cm^{-1}, 0.2 K in 200-300 cm^{-1} and 1100- 1300 cm^{-1}
Threshold = 0.25 K in 200-1300 cm^{-1}

FORUM Radiometric Precision

Clear sky

Sensitivity study to water vapour perturbation for different scenarios



Goal = 0.4 mW/(m² sr cm⁻¹) in 200-800 cm⁻¹, 1 mW/(m² sr cm⁻¹) elsewhere

Threshold = 0.6 mW/(m² sr cm⁻¹) in 200-800 cm⁻¹, 2 mW/(m² sr cm⁻¹) elsewhere

FORUM Summary

- FORUM is the 9th ESA Explorer Mission
- Selection announced 9/24/19 after a 1.5 year Phase A competition
- Instrument specifics pending ESA selection of Industry Partner/Vendor
  - ESA competes the flight instrument build separately from the science team
  - Two Industry teams competing
  - FORUM's Mission Advisory Group provided input on science and measurement requirements
- FORUM opens a new window on our understanding of the climate system
- Strong synergy with CERES
  - FORUM and CERES will have SNO's in polar regions
- Launch NET 2025

Backup Slides

FORUM Mission Objectives

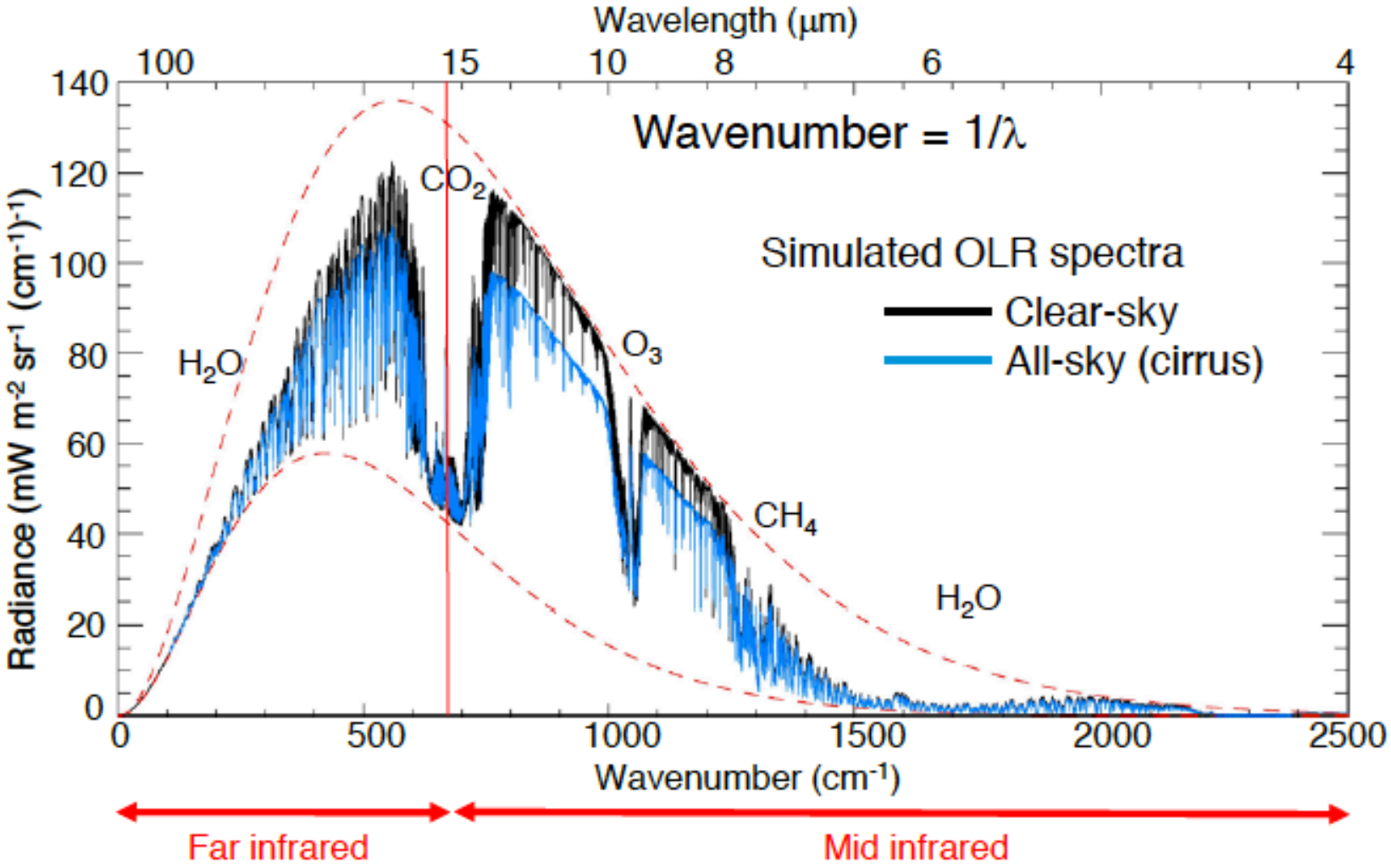
Primary

- Measure the spectral distribution of the Earth's OLR encompassing, for the first time, the far-ir
- Evaluate the underlying spectroscopy and cloud models currently employed in the far-ir
- Tie the observed radiative signatures directly to variability in, in particular, water vapour, greenhouse gases, cloud and surface properties
- Provide a stringent evaluation of key radiative processes/feedback mechanisms as currently represented in climate models

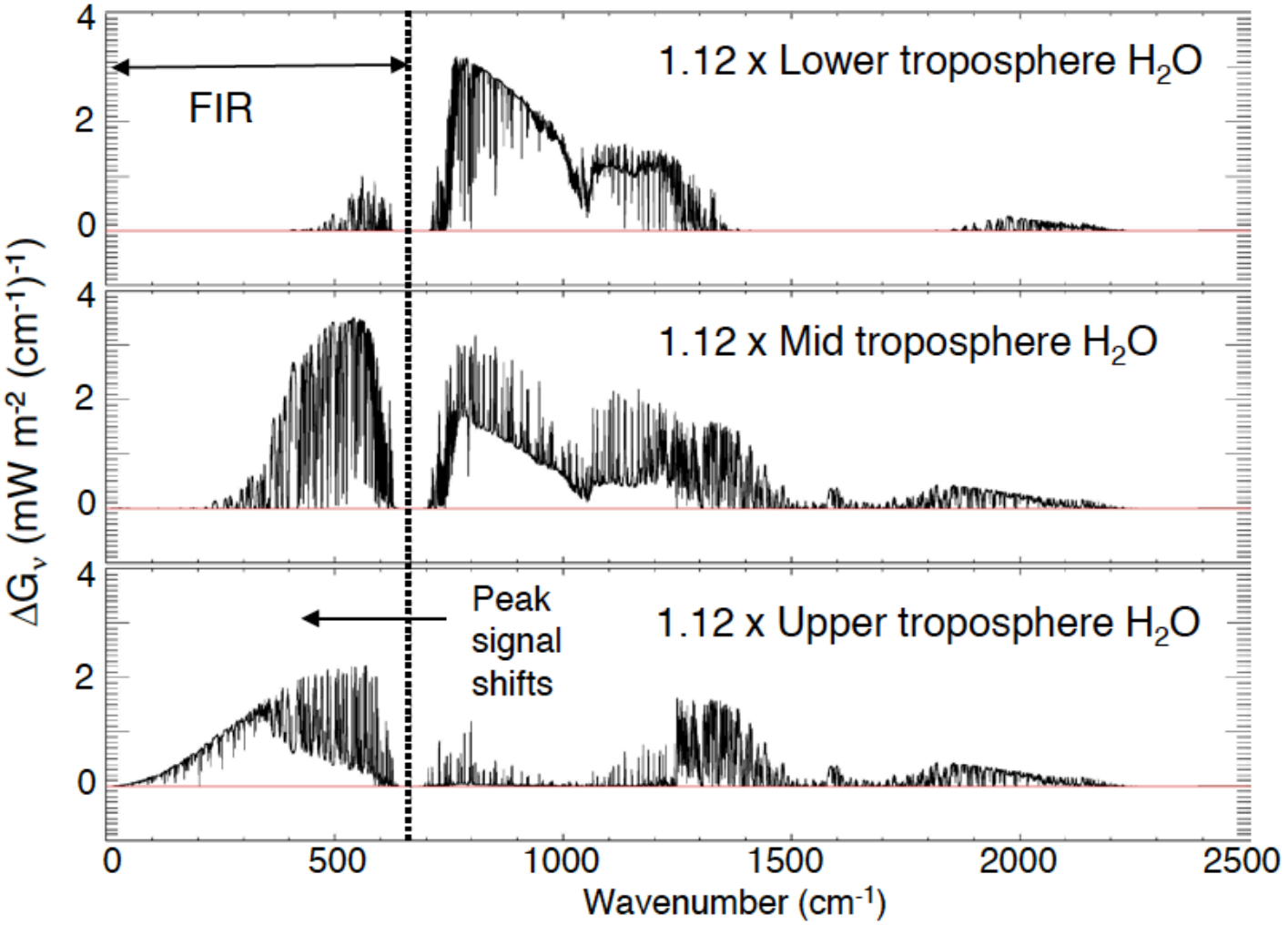
Additional

- Retrieval of FIR surface emissivity in appropriate conditions (clear-sky, dry conditions)
- Assessment of additional benefit of FIR spectral observations compared to state-of-the-art hyperspectral mid-infrared radiances for water vapour retrieval
- Detection of optically thin and sub-visual ice-cloud
- Retrieval of ice-cloud optical depth, cloud top height and particle size

Why the Far-Infrared?



Far-Infrared: Sensitivity to upper troposphere H_2O



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